Internal Antenna for Mobile Communications Device

Field of the Invention

This invention relates to an internal antenna for a mobile communications device such as a mobile telephone.

Background

It is common for the rf stage of a mobile communications device to include a balanced power amplifier stage. The main advantages of balanced power amplifiers include lower distortion and better rejection of power supply noise. Power amplifiers designed for mobile communications equipment typically have an output impedance of around 5 ohms, requiring an impedance matching network to connect to a conventional antenna which is generally designed to have a 50 ohm impedance.

Summary of the Invention

According to a first aspect of the invention, there is provided a balanced antenna for connecting to a balanced power amplifier stage in a portable communications device, the balanced power amplifier stage having first and second outputs, the antenna comprising a ground plane and first and second antenna elements spaced apart from each other and from the ground plane, wherein the antenna elements are arranged to be opposite one another and each of the antenna elements has a feed point connectable to one of the outputs from the power amplifier stage.

The balanced antenna according to the invention can interface directly to a balanced power amplifier (PA) stage without the need for a lossy conversion network. When a balanced antenna is used, the printed circuit board (PCB) of the mobile communications device is not part of the antenna. By contrast, in a single ended antenna, the PCB is part of the antenna and a large portion of the radiated rf signal is emitted from the telephone's PCB. Therefore, for a balanced antenna, the antenna induced currents in the ground plane of the PCB are much smaller and less likely to cause disturbances in the telephone's electronics.

The antenna according to the invention can be tuned to impedances between about 3 to 15 ohms, so that the balanced PA stage, which typically has an output impedance of around 5 ohms, can be connected directly to the antenna without an impedance matching network.

The elements can be substantially identical and one element can be reversed with respect to the other.

The balanced antenna can include a floating ground between the ground plane and the antenna elements. Advantageously, the floating ground avoids the problem of a component mounted on the printed circuit board (PCB) under the antenna affecting the impedance to ground of the radiating element of the antenna closest to the component. It also avoids disturbance of the operation of the component by the antenna field and so can make it possible to utilise the PCB area under the antenna.

According to the invention, there is also provided a portable communications device comprising a circuit board having a plurality of electronic components mounted thereon and a balanced antenna, the balanced antenna comprising first and second substantially parallel antenna elements mounted to the board, each of the antenna elements having a top edge and a bottom edge, the bottom edge being nearer the board than the top edge, the device further comprising a ground plane disposed between the bottom edge of the antenna elements and the board, the ground plane being electrically isolated from the antenna elements and the board.

In another aspect, the invention provides a balanced antenna for a portable communications device, comprising a ground plane and first and second substantially similar antenna elements spaced from the ground plane, the first and second elements being substantially parallel to the ground plane and being aligned in opposite directions with respect to one another.

According to the invention, there is further provided a method of manufacturing a balanced antenna for connecting to a balanced power amplifier stage in a portable communications device, the balanced power amplifier stage having first and second

outputs, the antenna comprising a ground plane and first and second antenna elements spaced apart from each other and from the ground plane, wherein the antenna elements are arranged to be opposite one another and to overlap to a predetermined extent, and each of the antenna elements has a feed point connectable to one of the outputs from the power amplifier stage, the method comprising varying the extent to which the antenna elements overlap to tune the antenna for use in a predetermined frequency band.

Description of the Drawings

Embodiments of the invention will now be described by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a perspective view of a mobile telephone handset;

Figure 2 is a rear view of the handset of Figure 1;

Figure 3 is a schematic diagram of mobile telephone circuitry for use in the telephone handset of Figure 1;

Figure 4 shows a first arrangement of a balanced antenna in accordance with the invention;

Figure 5 shows a second arrangement of a balanced antenna in accordance with the invention;

Figure 6 shows a Smith chart for the first antenna arrangement shown in Figure 4;

Figure 7 shows the frequency response for the first arrangement shown in Figure 4;

Figure 8 shows a Smith chart for the second arrangement shown in Figure 5;

Figure 9 shows the frequency response for the second arrangement shown in Figure 5;

Figure 10 shows a further embodiment of the invention including a floating ground;

Figure 11a illustrates the electric fields generated by a balanced antenna in the absence of a floating ground;

Figure 11b illustrates the electric field generated by a balanced antenna in the presence of a floating ground;

Figure 12 is a perspective view showing a further example of a balanced antenna comprising two opposed elements;

Figure 13 is a side view of the antenna of Figure 12, showing the various layers;

Figure 14 is a detailed view of one of the elements shown in Figure 12;

Figure 15 is a top view of the antenna of Figure 12, showing the arrangement of the elements;

Figure 16 is a Smith chart for the antenna of Figure 12; and

Figure 17 shows the frequency response of the antenna of Figure 12.

Detailed Description

Referring to Figure 1, a mobile station in the form of a mobile telephone handset 1 includes a microphone 2, keypad 3, with soft keys 4 which can be programmed to perform different functions, an LCD display 5, a speaker 6 and an antenna 7 which is contained within the housing. The location of the antenna 7 is illustrated in Figure 2, which shows the back of the handset 1 with a rear cover 8 removed.

The mobile station 1 is operable to communicate through cellular radio links with individual public land mobile networks (PLMNs), shown schematically as PLMN A and PLMN B. PLMNs A and B may utilise different frequency bands. For example, PLMN A is a GSM 1800 MHz network and PLMN B is a GSM 900 MHz network.

Generally, the handset communicates over a cellular radio link with its home network PLMN A (shown as HPLMN) in a first configuration i.e. using a frequency band appropriate to PLMN A. However, when the user roams to PLMN B, one of the keys on the handset, for example, one of the soft keys 4, may be operated to select a second operational configuration i.e. a frequency band associated with PLMN B.

Figure 3 illustrates the major circuit components of the telephone handset 1. Signal processing is carried out under the control of a digital micro-controller 9 which has an associated flash memory 10. Electrical analogue audio signals are produced by microphone 2 and amplified by pre-amplifier 11. Similarly, analogue audio signals are fed to the speaker 6 through an amplifier 12. The micro-controller 9 receives instruction signals from the keypad and soft keys 3, 4 and controls operation of the LCD display 5.

Information concerning the identity of the user is held on a smart card 13 in the form of a GSM SIM card which contains the usual GSM international mobile subscriber identity (IMSI) and an encryption key K_i that is used for encoding the radio transmission in a manner well known per se. The SIM card is removably received in a SIM card reader 14.

The mobile telephone circuitry includes a codec 15 and an rf stage 16 including a balanced power amplifier stage 17 feeding the antenna 7. The codec 15 receives analogue signals from the microphone amplifier 11, digitises them into a GSM signal format and feeds them to the rf stage 16 for transmission through the antenna 7 to the PLMN shown in Figure 1. Similarly, signals received from the PLMN are fed through the antenna 7 to be demodulated in the rf stage 16 and fed to codec 15, so as to produce analogue signals fed to the amplifier 12 and speaker 6.

Referring to Figure 4, an antenna 7 according to the invention comprises a first planar conductive plate 20 spaced apart from and generally parallel to a second planar conductive plate 21. Each of the first and second conductive plates 20, 21 forms a rectangular patch antenna element 18mm long and 3mm wide. A conductive leg 22 extends from a bottom corner of each conductive plate 20, 21, the leg 22 resting on a non-conductive pad 23 on a third conductive plate 24 forming a ground plane, the first and second plates 20, 21 being substantially perpendicular to the third plate 24. The third conductive plate 24 is for example the printed circuit board (PCB) to the underside of which the handset components are mounted. Each antenna element 20, 21 is connected to the rf stage 16 shown in Figure 3 via a feed point 25 located on the leg 22. The non-conductive pad 23 provides electrical isolation between the third plate 24 and the feed point 25.

The antenna could be constructed by using a "two-shot moulding" (MID) technique which enable the antenna elements to be fixed in the proper positions. The MID technique provides for air between the elements and plastic on their reverse sides to fix the antenna elements. Air between the elements, where the electrical field is at a maximum, minimises the electrical loss in the antenna. However the antenna can

also be made having mouldable plastic between the antenna elements and air at the reverse sides. In this case low loss plastic materials are preferably used.

During the development phase, the antenna 7 is tuned by changing the relative position of the two slot elements 20, 21, which changes the capacitive coupling between the elements. The inductive coupling between the elements is also controlled by displacement of the elements, as shown in Figure 5.

Figure 4 shows one extreme of relative position in which the elements overlap completely. This arrangement is close to that of a slot antenna. The other extreme of position (not shown) is obtained by moving the legs 22 of each of the patch elements close together so that the elements extend in opposite directions and do not overlap to any substantial extent. This arrangement is effectively a dipole antenna. Figure 5 shows a dipole-like antenna structure where the overall arrangement is similar to Figure 4 but in which the geometry of the plates and support structure is slightly different, so that the antenna elements 20, 21 do not overlap at all. The slot antenna elements 20, 21 are substantially rectangular elements 10mm long by 3mm wide, with an arm 26 1mm wide extending from one side of each of the elements to meet the supporting leg 22 at right angles.

Of course, it is possible to tune the antenna in a variety of other ways, including changing the plate dimensions or shape or changing the distance between the elements.

Figure 6 shows the Smith chart for the first arrangement described above in relation to Figure 4, while Figure 7 illustrates the frequency response of the arrangement, showing a resonant frequency at 0.9GHz, so that the antenna is suitable for use at the GSM 900MHz band. The bandwidth of the antenna is approximately 12 % having a return loss (S11) less than –8 dB.

Figure 8 shows the Smith chart for the second arrangement described above in relation to Figure 5, while Figure 9 illustrates the frequency response of the

arrangement, showing a resonant frequency at 1.85GHz, so that the antenna is suitable for use at the GSM 1800MHz and 1900MHz bands.

Figure 10 shows a balanced antenna as described above in relation to Figure 4, with the addition of a floating ground 27. The floating ground 27 is an area of conductive material made of same material as the balanced antenna. The floating ground 27 is disposed between the antenna elements 20,21 and the PCB 24, for example 1 mm from the bottom of the antenna elements 20, 21 and 2 mm from the PCB 24. The length of the floating ground is made approximately 2 mm shorter than the antenna elements 20,21. The floating ground 27 is supported on an area of dielectric-like plastic 28 which is used in the MID technique and has no electrical connections to the ground plane 24 or the antenna plates 20, 21. Since the fields emitted from the two parts 20, 21 of the balanced antenna are identical in magnitude and opposite in phase, the floating ground has the properties of an electrical ground.

The purpose of the floating ground is illustrated in Figures 11a and 11b. Figure 11a shows the electric field generated when the antenna is in use between the first and second antenna elements 20, 21, the PCB 24 and a component 29 mounted to the PCB 24. The electric field 30 between the first antenna element 20 and the PCB 24 is altered by the presence of the component 29, by comparison with the field 31 between the second antenna plate 21 and the PCB 24. The effect of the position of the first element 20 of the balanced antenna 7 over the component 29 is to lower the impedance to ground for the first antenna element 20, which can significantly alter antenna behaviour.

Figure 11b illustrates the effect of introducing a floating ground 27. The electric fields 32, 33 between each of the antenna elements 20, 21 and the floating ground 27 are unaffected by the presence of the component 29 on the PCB. The use of a floating ground 27 therefore makes the PCB area under the antenna 7 available for mounting electrical components. The components will not affect antenna operation and their operation will in turn be unaffected by the antenna field.

Figures 12 and 13 show a further embodiment of a balanced antenna. The antenna comprises first and second substantially identical conductive elements 35, 36 disposed on either side of a 1mm thick dielectric layer 37, comprising a material with a high dielectric constant, for example greater than 8, such as ceramics materials. The dielectric layer 37, shown in Figure 13 only for clarity, is spaced 3mm above a ground plane 38, for example the PCB to which the handset components are mounted. The dielectric layer 37 is connected to a non-conductive leg 39 which extends down to the PCB and so supports the antenna structure above the ground plane 38. The conductive elements 35, 36, dielectric layer 37 and ground plane 38 are substantially parallel with respect to one another.

As shown in Figure 14, each element 35, 36 comprises a central spur 40 3mm long and 1mm wide connected on either side, at one end, to substantially identical panels 5.5mm long by 5.1 mm wide. Overall, each element 35, 36 is substantially rectangular, 14mm long by 5.1mm wide and has a feed point 41 at the free end of the spur 40. As shown in Figure 15, the elements 35, 36 are arranged overlapping and opposite one another, one element 35 being reversed with respect to the other 36 so that the feed points 41 are at opposite ends of the antenna arrangement.

The antenna described above in relation to Figures 12 to 15 has similar properties to the balanced antenna shown in Figures 4 and 5, in terms of its easy interfacing to a balanced power amplifier stage without a lossy conversion network and the fact that antenna induced currents in the ground plane of the PCB are relatively small. It can be shown that there is some current on the PCB but it is fairly independent of the PCB position, both in terms of height and orientation. For example, turning the antenna by 90° would turn the radiation pattern by 90°. However, dipole operation is not obtained no matter how the radiating elements are positioned with respect to one another.

Figure 16 is a Smith chart of the impedance at the balanced input. This shows the low impedance nature of the input. Figure 17 shows the frequency response of this antenna arrangement. The antenna has a resonant frequency at 0.94 GHz, where it has a real impedance of 7.4 ohms.

It will be understood that while the antenna arrangement has been described with detailed dimensions and relative arrangement of conductive plates, this is merely a specific example of the invention, and modifications to the dimensions and precise arrangement of the components which do not alter the principles of operation also fall within the scope of this invention.